(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 February 2001 (15.02.2001)

PCT

(10) International Publication Number
WO 01/10499 A1

(51) International Patent Classification[7]: A61N 1/368 // 1/365

(21) International Application Number: PCT/SE00/01309

(22) International Filing Date: 19 June 2000 (19.06.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
9902848-2 5 August 1999 (05.08.1999) SE

(71) Applicant *(for all designated States except US)*: **ST. JUDE MEDICAL AB** [SE/SE]; S-175 84 Järfälla (SE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **OBEL, Martin** [SE/SE]; Bergavägen 5, S-182 33 Danderyd (SE). **SKANSÉN, Jan** [SE/SE]; Box 8, S-134 06 Ingarö (SE).

(74) Common Representative: **ST. JUDE MEDICAL AB**; Patent Department, S-175 84 Järfälla (SE).

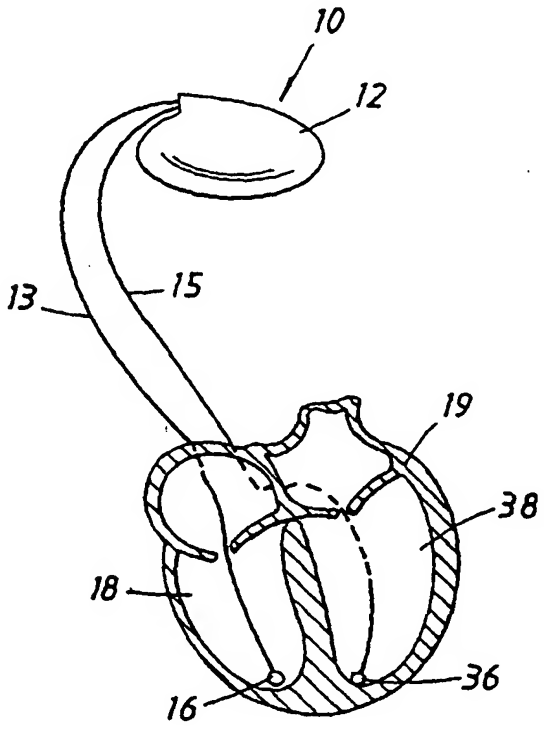
(81) Designated State *(national)*: US.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: A CARDIAC STIMULATING DEVICE



(57) **Abstract:** The invention concerns an implantable cardiac stimulating device (10). The device comprises a control circuit (14) adapted to be connected to a first (16) and second (36) electrode in order to stimulate a first (18) and second (38) ventricle of the heart. The device (10) comprises means (24, 44) for sensing evoked response parameters for the two ventricles (18, 38). The control circuit (14) comprises means (46) to enable the delivery of the stimulating pulses (21) to the electrodes (16, 36) within the same cycle of the heart such that there may be a time interval (dT) between them. The control circuit (14) controls the delivery of the stimulating pulses (21) such that the evoked response parameters of the two ventricles (18, 38) occur substantially simultaneously.

WO 01/10499 A1

A cardiac stimulating device

BACKGROUND OF THE INVENTION

1. Field of the invention

The present invention relates to an implantable cardiac stimulating device. More precisely, the invention concerns such a stimulating device comprising a housing, a control circuit enclosed in the housing, said control circuit being adapted to be connected to a fist electrode to be positioned to stimulate a first ventricle of the heart. The control circuit is also adapted to be connected to a second electrode to be positioned to stimulate the second ventricle of the heart. The control circuit also comprises means for delivering stimulating pulses to the first and second electrodes. Furthermore, the device comprises means for sensing at least one evoked response parameter to the stimulation of the first and second ventricles.

2. Description of the prior art

Most pacers are arranged to stimulate the right ventricle of the heart, but it is also known to stimulate the left ventricle. In particular for the treatment of congestive heart failure or other severe cardiac failures it is known to stimulate the left ventricle, or both ventricles, in order to optimize the hemodynamic performance of the heart.

US-A-5 728 140 describes a method and an apparatus for pacing the left ventricle of the heart. The pacing electrode is positioned within the interventricular septum proximate the left ventricular wall thereof.

US-A-5 720 768 describes different possible electrode positions in order to stimulate or sense the different chambers of the heart.

Also the article "A Method for Permanent Transvenous Left Ventricular Pacing" by Blanc et al, PACE, Vol. 21, 1998, pp. 2021-2024, describes a method for positioning leads for left ventricular pacing.

US-A-4 928 688 describes a method and an apparatus for treating patients suffering from congestive heart failure by stimulating both the ventricles. The document discusses the problem involved when the left and right ventricles contract in asynchrony. In order to effect substantially simultaneous contraction of both ventricles, the document suggests means for separately processing sensed cardiac signals from each of the right and left ventricles. If ventricular contractions are not sensed in both ventricles within a period of coincidence defined by a time delay, the pacing pulse will be emitted at the end of this time delay, but only to the ventricle for which a QRS-complex has not been sensed. The time delay is suggested to be in the order of 5-10 ms.

SUMMARY OF THE INVENTION

The purpose of pacing the left and right ventricles with separate leads is to improve the synchronization of the mechanical contraction of the two ventricles. The synchronization of the ventricles is very important for patients with severe congestive heart failure. These patients are often waiting for a heart transplant and optimal hemodynamic conditions during the time before the transplant is important for the outcome. A problem in this context is that synchronous pacing will not necessarily provide the best possible synchronization of the actual

contraction of the ventricles. The present inventors have found that the synchronization of the ventricles may be improved compared to previous known devices if the cardiac stimulating device comprises particular means for adjusting the timing of the stimulating pulses in order to optimise the synchronization in the contraction of the ventricles. It is thus an object of the present invention to provide an implantable cardiac stimulating device by means of which the synchronization of the ventricles is improved.

The object of the invention is obtained by an implantable cardiac stimulating device, comprising:

a housing,

a control circuit enclosed in said housing, said control circuit being adapted to be connected to a first electrode to be positioned to stimulate a first ventricle of the heart,

said control circuit also being adapted to be connected to a second electrode to be positioned to stimulate a second ventricle of the heart,

said control circuit comprising means for delivering stimulating pulses to said first and second electrodes in order to stimulate the first and second ventricles, respectively,

wherein the control circuit comprises means arranged to enable the delivery of the stimulating pulses to said first and second electrodes within the same cycle of the heart such that there may be a time interval between them, wherein the control circuit is arranged such that said time interval is variable,

means arranged for sensing at least one evoked response parameter to stimulation for the first and second ventricles, respectively,

wherein the control circuit comprises means arranged to compare the occurrence in time of the sensed evoked response parameter to stimulation of the first ventricle with the

sensed evoked response parameter to stimulation of the second ventricle, and

wherein the control circuit comprises means arranged to control the delivery of stimulating pulses to said first and second electrodes such that the difference in occurrence in time between said sensed evoked response parameter to stimulation of the first ventricle and said sensed evoked response parameter to stimulation of the second ventricle is minimized.

According to the invention, the stimulating pulses to the ventricles are delivered at such times that the sensed evoked response parameters to the left and right ventricles occur substantially simultaneously. Since the evoked responses are better related to the actual contraction of the ventricles then the delivery of the pacing pulses, an improved synchronization may be obtained by the present invention.

According to a further embodiment of the invention, said means arranged for sensing at least one evoked response parameter to stimulation for the first and second ventricles are arranged for sensing an electrical evoked response parameter. Such an electrical evoked response parameter may be sensed by, for example, the electrodes used for stimulating the ventricles.

According to a further embodiment of the invention, said control circuit is arranged such that said comparison is made by comparing the R-wave in the evoked response to the stimulation of the first ventricle with the R-wave in the evoked response to stimulation of the second ventricle. The R-wave is also called the QRS-complex. The R-wave is more closely related to the ventricular contraction than the delivered stimulating pulse. By making the R-waves in the left and right ventricles occur substantially

simultaneously, a good synchronization of the ventricles is obtained.

According to still another embodiment of the invention, the control circuit is arranged such that said comparison is made by measuring an integral of the difference between said R-wave in the evoked response to the stimulation of the first ventricle and said R-wave in the evoked response to stimulation of the second ventricle, wherein said time interval is set such that said integral is minimized. Since the R-wave in the evoked response to stimulation of the left ventricle may have a slightly different shape than the R-wave in the evoked response to stimulation of the right ventricle, the inventors have found that by minimizing said integral a substantially simultaneous contraction of the left and right ventricles is obtained.

According to a further embodiment of the invention, said integral is measured over a predetermined time period after stimulation. This predetermined time period can be related either to the stimulation of the left or of the right ventricle. It is thereby not necessary to exactly detect the beginning and the end of the R-waves. However, the predetermined time period is selected to essentially correspond to the extension in time of the R-waves.

According to a further embodiment of the invention, the control circuit is arranged such that said comparison is made by comparing the occurrence in time of a slope or peak of the R-wave in the evoked response to the stimulation of the first ventricle with the occurrence in time of the corresponding slope or peak of the R-wave in the evoked response to stimulation of the second ventricle, wherein said time interval is set such that the difference in occurrence in time between said slopes or peaks is minimized. Instead of using the above-mentioned integral, it

is possible to detect another point on the R-wave curve. For such a point it is suitable to use either a slope or a peak. The slope may be either negative or positive. For example, the maximum negative or positive slope may be used.

According to still another embodiment of the invention, the control circuit is arranged to set said time interval by first varying said time interval and by comparing the corresponding evoked response parameters for the different time intervals, and then setting said time interval such that said integral is minimized or said difference in occurrence in time between said slopes or peaks is as small as possible. In this way an optimal time interval may be found by an iterative process. The difference in occurrence in time between said slopes or peaks may be continuously monitored, such that the time interval is adjusted such that the contractions of the left and right ventricles occur substantially simultaneously.

According to a further embodiment of the invention, the control circuits are arranged such that the sensed evoked response parameter is a unipolar sensed evoked response parameter. It has been found that a unipolar sensed evoked response parameter is suitable for detecting the R-wave. However, it is also possible to use bipolar sensing.

According to a further embodiment of the invention, the control circuit is arranged such that said comparison is made by comparing the T-wave in the evoked response to the stimulation of the first ventricle with the T-wave in the evoked response to stimulation of the second ventricle. The T-wave represents ventricular repolarisation. This wave is a good indication of the ventricular contraction.

According to still another embodiment of the invention, the control circuit is arranged such that said comparison is

made by measuring an integral of the difference between said T-wave in the evoked response to the stimulation of the first ventricle and said T-wave in the evoked response to stimulation of the second ventricle, wherein said time interval is set such that said integral is minimized. In the same manner as described above in connection with the R-wave, it is possible to make the contraction of the ventricles occur substantially simultaneously by minimizing the corresponding integral for the T-waves.

According to a further embodiment of the invention, said integral is measured over a predetermined time period after stimulation.

Furthermore, in a similar manner as to what has been described above in connection with the R-wave, it is possible to detect a slope or peak of the T-wave in the evoked response to stimulation of the ventricles. Also, in a manner similar to what has been described above it is advantageous to set said time interval by varying the time interval and by comparing the corresponding evoked response parameters.

According to still a further embodiment of the invention, the control circuit is arranged such that the sensed evoked response parameter is a bipolar sensed evoked response parameter. Such a bipolar sensing has been shown to be advantageous for detecting the T-wave. However, it is also possible to use unipolar sensing.

According to another embodiment of the invention, said means arranged for sensing at least one evoked response parameter to stimulation for the first and second ventricles are arranged for sensing a mechanical evoked response parameter. The mechanical evoked response parameter may constitute the actual contraction of the respective ventricle. Such a

mechanical response parameter may be sensed by, for example, an accelerometer, means for sensing pressure or means for sensing the impedance. An advantage with the sensing of a mechanical evoked response parameter is that this parameter is directly indicative of the contraction of the ventricles.

According to a further embodiment of the invention, the device comprises means for varying the rate of stimulating pulses up to a maximum pacing rate,

wherein the control circuit comprises means arranged to measure the time gap between a stimulating pulse and the associated evoked response parameter sensed by said means for sensing for at least one of the first and second electrodes,

means for monitoring said time gap at the varying pacing rates with which the stimulating pulses are delivered,

and wherein the control circuit is arranged such that said maximum pacing rate is lowered if said time gap does not decrease with increasing pacing rate.

The inventors of the present invention have found that the time gap between a stimulating pulse and the associated evoked response parameter may be monitored in order to detect heart problems, such as dissynchronization. Normally, when the pacing rate increases, the time gap between a stimulating pulse and the associated evoked response parameter becomes shorter. However, at a certain pacing rate, said time gap may stop decreasing although the pacing rate increases. The present inventors have found that such a situation is an indication of heart problems, such as a dissynchronization between the ventricles. According to this embodiment of the invention, an implantable cardiac stimulating device is provided which is such that the patient carrying the device will be exposed to less risk, since the maximum pacing rate is lowered if the mentioned

time gap does not decrease with increasing pacing rate.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig 1 is a schematic representation of a device according to the invention connected to a heart;

Fig 2 is a block diagram of a control circuit of a device according to the invention;

Fig 3 is a schematic representation of an electro-cardiographic response signal to a stimulating pulse;

Fig 4 is a schematic graphical representation of the relationship between a time gap and the pacing rate;

Fig 5a,b,c are schematic representations of typical electro-cardiographic response signals to stimulation of the left and right ventricles.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig 1 shows an implantable cardiac stimulating device 10, hereinafter also called a pacemaker, according to the invention. The pacemaker 10 comprises a housing 12. A control circuit 14 (see Fig 2) is enclosed in the housing 12. The control circuit 14, and thereby the pacemaker 10, is adapted to be connected to a first electrode 16. Fig 1 shows such an electrode 16 which is connected to the pacemaker 10 via a lead 13. The first electrode 16 is adapted to be positioned to stimulate a first ventricle 18 of the heart 19. The first ventricle 18 is in this case the right ventricle. According to the invention, the pacemaker 10 is also adapted to be connected to a second electrode 36. Fig 1 shows such a second electrode 36 connected to the housing 12 via a lead 15. The second electrode 36 is positioned to stimulate a second ventricle 38 of the heart 19. The second

ventricle 38 is in this case the left ventricle. The electrodes 16, 36 may include more than one electrical conductor in order to allow for bipolar pacing and sensing.

Fig 2 shows a schematic representation of a block diagram of a control circuit 14 which is enclosed in the housing 12 of the pacemaker 10. The control circuit 14 comprises means 20, 40 for delivering stimulating pulses 21 to the first 16 and second 36 electrodes. The control circuit 14 comprises means 24 arranged for sensing at least one evoked response parameter of said first ventricle 18 to the stimulating pulses delivered via said first electrode 16. The pacemaker 10 also comprises means 44 arranged for sensing at least one evoked response parameter to the stimulation of the second ventricle 38. The evoked response parameter may either be a parameter which indicates a mechanical contraction of the ventricle 18 or a parameter indicating an electrical response. The mechanical contraction may, for example, be sensed by an accelerometer, a pressure sensor or an impedance sensor. The impedance may, for example be sensed by an electrode 16, 36 connected to the pacemaker 10. The evoked response parameter may also be an electrical evoked response parameter which is sensed, for example, by the electrode 16, 36 positioned in the ventricle. Such an electrical evoked response parameter may be, for example, the T-wave or the R-wave in the electrical evoked response.

The control circuit 14 also comprises means 46 arranged to enable the delivery of the stimulating pulses to the first 16 and the second 36 electrodes within the same cycle of the heart such that there may be a time interval dT between them (see Fig 5c). Furthermore, the control circuit 14 is arranged such that said time interval dT is variable. The control circuit 14 comprises means 48 arranged to compare the occurrence in time of the sensed evoked response parameter to the stimulation of the first ventricle 18 with

the sensed evoked response parameter to the stimulation of the second ventricle 38. The control circuit 14 also comprises means 50 arranged to control the delivery of the stimulating pulses to the first 16 and second 36 electrodes such that the difference in occurrence in time ΔT between the sensed evoked response parameter to the stimulation of the first ventricle 18 and said sensed evoked response parameter to the stimulation of the second ventricle 38 is minimized.

The invention is further illustrated in Fig 5a, 5b, 5c. The evoked response parameter may be a mechanical or an electrical sensed evoked response parameter as explained above. Fig 5a, 5b, 5c show typical electrical evoked responses. The electrical evoked response parameter may be related to either the R-wave (QRS-complex) or the T-wave. Moreover, different alternatives exist for detecting the evoked response. The evoked response parameter may for example be a peak or a maximum 52 or a certain predetermined slope 54, 55 of the wave which is detected. Also other possible points on the curve in the electrical evoked response may be detected, e.g. a zero-crossing. Instead of directly comparing the occurrence in time of a slope or peak or other point on the respective wave, it is possible to measure an integral of the difference between the wave in question in the evoked response to the stimulation of the first ventricle 18 and the wave in the evoked response to the stimulation of the second ventricle 38. The time interval dT is thereby set such that said integral is minimized. The integral is preferably measured over a predetermined time period after a stimulating pulse. For example, for detecting the R-wave the time period may start 10 ms after the delivery of the last stimulating pulse and end 40 ms later. The sensing of the evoked response may be done either with a unipolar or with a bipolar arrangement. When the R-wave is sensed it may be advantageous to use a

unipolar sensing. When the T-wave is sensed it may be advantageous to use a bipolar sensing.

In Fig 5b an example is shown where the peak of the R-wave is detected. The curve 56 represents the electrical evoked response to a stimulation pulse 21 for the first ventricle 18. The curve 57 represents the corresponding evoked response for the second ventricle 38. According to this example, the stimulating pulses 21 to the first 16 and the second 36 electrodes are delivered simultaneously. In the example shown, the peak of the curve 56 occurs before the peak of the curve 57. The difference in occurrence in time between the peaks of the curves 56 and 57 is represented by ΔT. According to this embodiment of the invention, the control circuit 14 thus comprises means 50 which delivers the stimulating pulses to the first 16 and second 36 electrodes at different times such that the difference in occurrence in time of the peaks of the curves 56 and 57 is minimized.

Fig. 5c illustrates that the stimulating pulse to the second ventricle 58 is delivered before the stimulating pulse to the first ventricle 18. Hereby the two peaks of the curves 56 and 57 occur substantially simultaneously (ΔT is equal to 0). In order to make the peaks occur simultaneously it is possible to either deliver the stimulating pulse to the electrode 36 (corresponding to the curve 57) earlier in time or to deliver the pulse to the electrode 16 (corresponding to the curve 56) later in time. A physician may determine which of the two possibilities is most suitable for a particular patient.

The pacemaker 10 may be of the kind which comprises means 22 for varying the pacing rate. The time interval dT may vary in dependence of the pacing rate. The control circuit 14 may hereby be arranged to take the pacing rate into account when

determining a suitable time interval dT. In other words, if the pacing rate increases, the control circuit 14 may be set to change the time interval dT such that the sensed evoked response parameters are likely to occur simultaneously. The evoked responses may then be continuously monitored such that the time interval dT is modified such that the evoked response parameters continuously occur simultaneously.

According to a further embodiment of the invention, the control circuit also comprises means 22 for varying the rate of stimulating pulses up to a maximum pacing rate M. The maximum pacing rate M may be the maximum sensor rate and/or the maximum track rate. The control circuit 14 also comprises means 26 arranged to measure a first time gap G between a stimulating pulse and the associated evoked response parameter sensed by said means for sensing 24.

Fig 3 shows a schematic representation of a typical electrical sensed response signal. A stimulating pulse is represented by the reference number 21. In the electrical response to such a stimulating pulse 21 an R-wave (also called QRS-complex) and a T-wave may be detected. In the example according to Fig 3 the sensed evoked response parameter is the T-wave. G represents the mentioned time gap between the stimulating pulse 21 and the associated evoked response parameter sensed by the means for sensing 24.

The control circuit 14 comprises means 28 for monitoring the first time gap G at the varying pacing rates with which the stimulating pulses 21 are delivered. The control circuit 14 is arranged such that said maximum pacing rate M is lowered if said first time gap G does not decrease with increasing pacing rate.

Fig. 4 shows a schematic representation of the relationship between the time gap G and the pacing rate. The pacemaker 10

normally has a preset, programmable maximum pacing rate M. The maximum pacing rate is represented with M in Fig 4. The time gap between a stimulating pulse 21 and the associated evoked response parameter normally decreases when the pacing rate increases. However, for some patients, for example those with a progressive heart disease which may alter the compliance patterns due to geometric remodelling of the myocardium, the heart disease may be such that the previously set maximum pacing rate M is in fact too high for the patient. According to this embodiment of the invention, the maximum pacing rate M is lowered if the mentioned first time gap G does not decrease with increasing pacing rate. In Fig 4 the point 29 on the curve is a point where the mentioned time gap G does not decrease with increasing pacing rate. When this point 29 is reached, the maximum pacing rate M is thus lowered according to the present invention.

The control circuit 14 may also comprise means 34 for monitoring the change in time gap ΔG when the pacing rate increases. The control circuit 14 is hereby arranged such that the maximum pacing rate M is lowered if the change in time gap ΔG is below a predetermined value. In Fig 4 two examples of ΔG are indicated. ΔG_1 is relatively large and ΔG_2 is smaller. When ΔG is below a predetermined value the maximum pacing rate M is thus lowered. Thereby the maximum pacing rate M may be lowered before the point 29 is reached. Thereby the risks to which the heart is exposed are reduced even further.

To return to Fig 2, the control circuit 14 may also comprise means 30 for storing the measured first time gap G for one or more pacing rates. The control circuit 14 further comprises means 32 arranged for comparing the present measured first time gap with a previously stored first time gap for the corresponding pacing rate. The control circuit

14 is arranged such that the maximum pacing rate M is lowered also in case of difference between the present measured first time gap and the corresponding stored first time gap exceeds a predetermined value. Thereby a further measure is taken in order to reduce the risk for the patient.

As explained above in connection with Fig 1, the pacemaker 10 is adapted to be connected to a second electrode 36. The means 26 arranged to measure the first time gap G may thereby also arranged to measure a corresponding second time gap between a stimulating pulse and the associated evoked response parameter of the second ventricle 38. The control circuit 14 is hereby arranged such that the maximum pacing rate M is lowered if at least one of said first and second time gaps does not decrease with increasing pacing rate.

The control circuit 14 may also be arranged such that the maximum pacing rate M is lowered also if the difference between the first and second time gaps exceeds a predetermined value. Thus the maximum pacing rate M is lowered also in this case, in order to further reduce the risks to which the patient is exposed.

The present invention is not limited to the above-described preferred embodiments. Various alternatives, modifications and equivalencies may be used. Therefore, the above embodiments should not be taken as limiting the scope of the invention, which is defined by the appendant claims.

Claims

1. An implantable cardiac stimulating device (10), comprising:

a housing (12),

a control circuit (14) enclosed in said housing (12), said control circuit (14) being adapted to be connected to a first electrode (16) to be positioned to stimulate a first ventricle (18) of the heart (19),

said control circuit (14) also being adapted to be connected to a second electrode (36) to be positioned to stimulate a second ventricle (38) of the heart (19),

said control circuit (14) comprising means (20, 40) for delivering stimulating pulses (21) to said first (16) and second (36) electrodes in order to stimulate the first (18) and second (38) ventricles, respectively,

wherein the control circuit (14) comprises means (46) arranged to enable the delivery of the stimulating pulses (21) to said first (16) and second (36) electrodes within the same cycle of the heart such that there may be a time interval (dT) between them, wherein the control circuit (14) is arranged such that said time interval (dT) is variable,

means (24, 44) arranged for sensing at least one evoked response parameter to stimulation for the first (18) and second (38) ventricles, respectively,

wherein the control circuit (14) comprises means (48) arranged to compare the occurrence in time of the sensed evoked response parameter to stimulation of the first ventricle (18) with the sensed evoked response parameter to stimulation of the second ventricle (38), and

wherein the control circuit (14) comprises means (50) arranged to control the delivery of stimulating pulses (21) to said first (16) and second (36) electrodes such that the difference in occurrence in time (ΔT) between said sensed evoked response parameter to stimulation of the first

ventricle (18) and said sensed evoked response parameter to stimulation of the second ventricle (38) is minimized.

2. An implantable cardiac stimulating device (10) according to claim 1, wherein said means (24, 44) arranged for sensing at least one evoked response parameter to stimulation for the first (18) and second (38) ventricles are arranged for sensing an electrical evoked response parameter.

3. An implantable cardiac stimulating device (10) according to claim 2, wherein the control circuit (14) is arranged such that said comparison is made by comparing the R-wave in the evoked response to the stimulation of the first ventricle (18) with the R-wave in the evoked response to stimulation of the second ventricle (38).

4. An implantable cardiac stimulating device (10) according to claim 3, wherein the control circuit (14) is arranged such that said comparison is made by measuring an integral of the difference between said R-wave in the evoked response to the stimulation of the first ventricle (18) and said R-wave in the evoked response to stimulation of the second ventricle (38), wherein said time interval (dT) is set such that said integral is minimized.

5. An implantable cardiac stimulating device (10) according to claim 4, wherein said integral is measured over a predetermined time period after stimulation.

6. An implantable cardiac stimulating device (10) according to claim 3, wherein the control circuit (14) is arranged such that said comparison is made by comparing the occurrence in time of a slope or peak of the R-wave in the evoked response to the stimulation of the first ventricle (18) with the occurrence in time of the corresponding slope

or peak of the R-wave in the evoked response to stimulation of the second ventricle (38), wherein said time interval (dT) is set such that the difference in occurrence in time (ΔT) between said slopes or peaks is minimized.

7. An implantable cardiac stimulating device (10) according to any of the claims 4 to 6, wherein the control circuit (14) is arranged to set said time interval (dT) by first varying said time interval (dT) and by comparing the corresponding evoked response parameters for the different time intervals (dT), and then setting said time interval (dT) such that said integral is minimized or said difference in occurrence in time (ΔT) between said slopes or peaks is as small as possible.

8. An implantable cardiac stimulating device (10) according to any of the claims 1 to 7, wherein the control circuit (14) is arranged such that the sensed evoked response parameter is a unipolar sensed evoked response parameter.

9. An implantable cardiac stimulating device (10) according to claim 2, wherein the control circuit (14) is arranged such that said comparison is made by comparing the T-wave in the evoked response to the stimulation of the first ventricle (18) with the T-wave in the evoked response to stimulation of the second ventricle (38).

10. An implantable cardiac stimulating device (10) according to claim 9, wherein the control circuit (14) is arranged such that said comparison is made by measuring an integral of the difference between said T-wave in the evoked response to the stimulation of the first ventricle (18) and said T-wave in the evoked response to stimulation of the second ventricle (38), wherein said time interval (dT) is set such that said integral is minimized.

11. An implantable cardiac stimulating device (10) according to claim 10, wherein said integral is measured over a predetermined time period after stimulation.

12. An implantable cardiac stimulating device (10) according to claim 9, wherein the control circuit (14) is arranged such that said comparison is made by comparing the occurrence in time of a slope or peak of the T-wave in the evoked response to the stimulation of the first ventricle (18) with the occurrence in time of the corresponding slope or peak of the T-wave in the evoked response to stimulation of the second ventricle (38), wherein said time interval (dT) is set such that the difference in occurrence in time (ΔT) between said slopes or peaks is minimized.

13. An implantable cardiac stimulating device (10) according to any of the claims 9-12, wherein the control circuit (14) is arranged to set said time interval (dT) by first varying said time interval (dT) and by comparing the corresponding evoked response parameters for the different time intervals (dT), and then setting said time interval (dT) such that said integral is minimized or said difference in occurrence in time (ΔT) between said slopes or peaks is as small as possible.

14. An implantable cardiac stimulating device (10) according to any of the claims 9-13, wherein the control circuit (14) is arranged such that the sensed evoked response parameter is a bipolar sensed evoked response parameter.

15. An implantable cardiac stimulating device (10) according to claim 1, wherein said means (24, 44) arranged for sensing at least one evoked response parameter to stimulation for the first (18) and second (38) ventricles

are arranged for sensing a mechanical evoked response parameter.

16. Am implantable cardiac stimulating device according to any of claims 1-15, comprising

means (22) for varying the rate of stimulating pulses up to a maximum pacing rate (M),

wherein the control circuit (14) comprises means (26) arranged to measure the time gap (G) between a stimulating pulse (21) and the associated evoked response parameter sensed by said means for sensing (24, 44) for at least one of the first (16) and second (36) electrodes,

means (28) for monitoring said time gap (G) at the varying pacing rates with which the stimulating pulses (21) are delivered,

and wherein the control circuit (14) is arranged such that said maximum pacing rate (M) is lowered if said time gap (G) does not decrease with increasing pacing rate.

Fig. 1

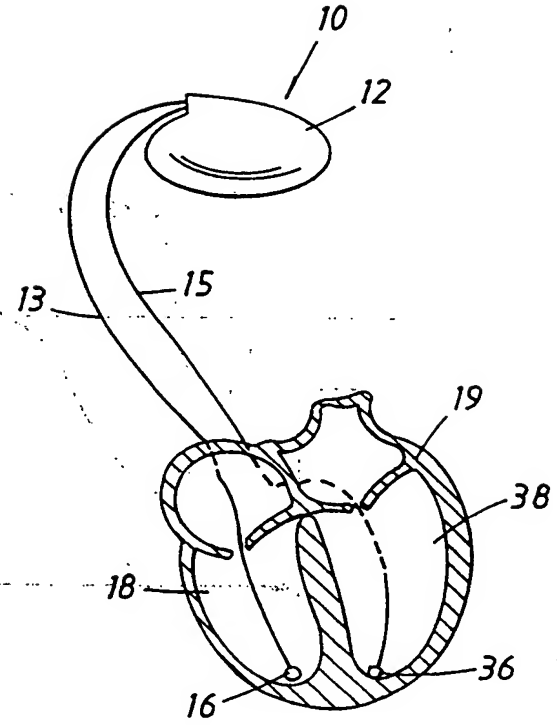

10
12
15
13
19
38
18
36
16

Fig. 2

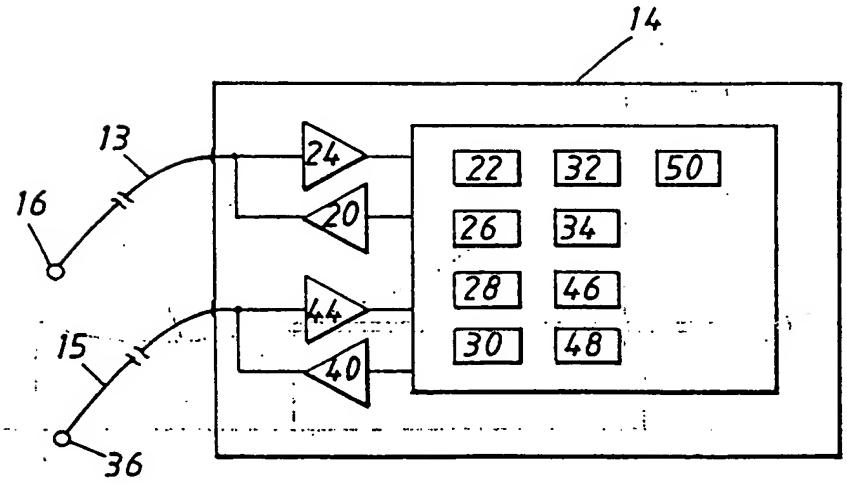

14
13
16
15
36
24
20
44
40
22
32
50
26
34
28
46
30
48

Fig. 3

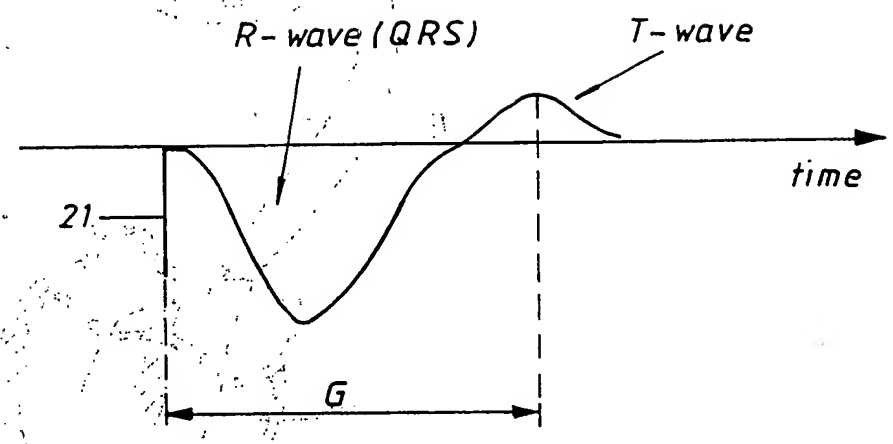


Fig. 4

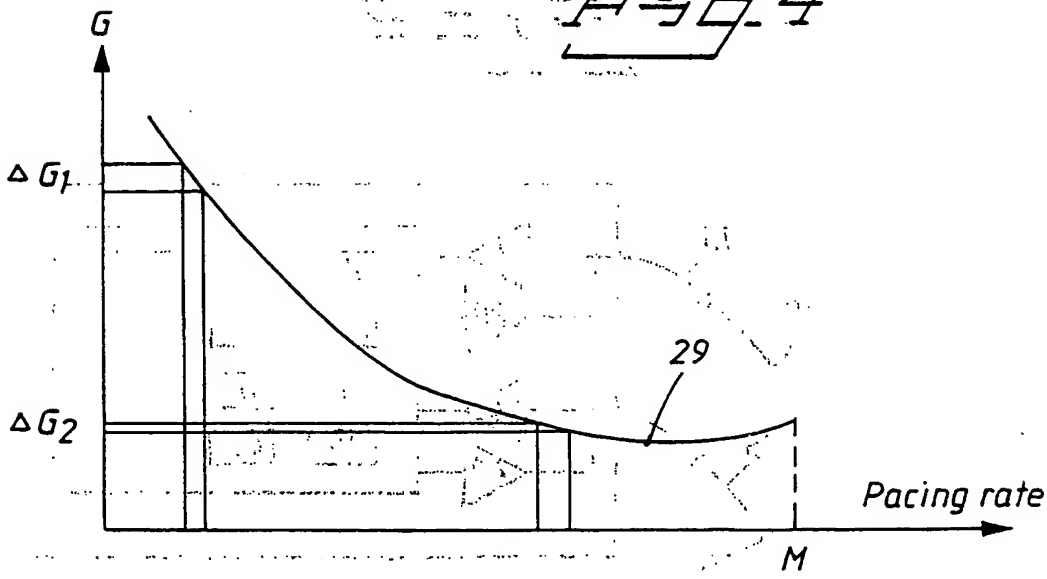


Fig. 5a

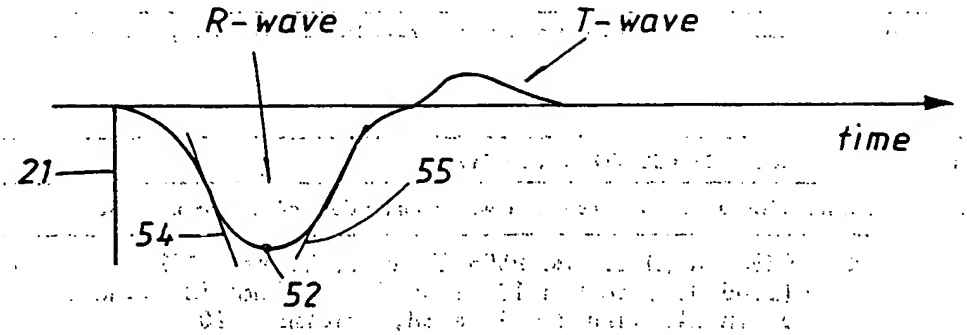


Fig. 5b

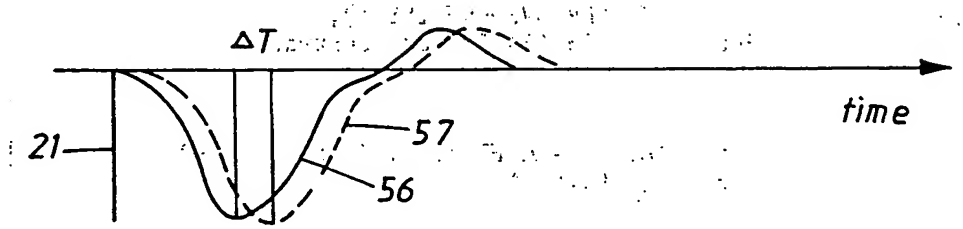
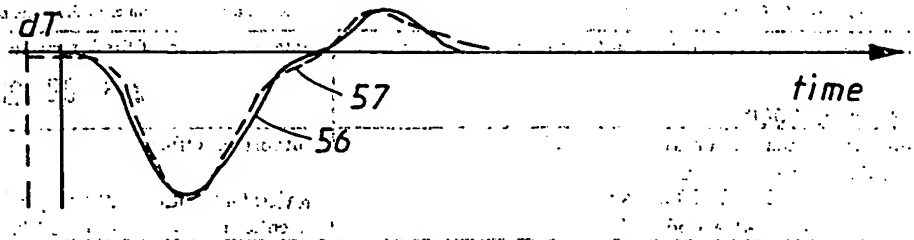


Fig. 5c



INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/01309

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: A61N 1/368 // A 61 N 1/365
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: A61N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5902324 A (D.L. THOMPSON ET AL.), 11 May 1999 (11.05.99), column 12, line 60 - column 13, line 2; column 24, line 8 - line 38, claims 1-20	1-3,6,8,9, 12,14
D,A	US 4928688 A (M.M. MOWER), 29 May 1990 (29.05.90), abstract	1-16
D,A	US 5720768 A (Y. VERBOVEN-NELISSEN), 24 February 1998 (24.02.98), abstract	1-16
D,A	US 5728140 A (R.W. SALO ET AL.), 17 March 1998 (17.03.98), abstract	1-16

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 Sept 2000	26 -09- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Nikolaj Hautaviita/AE Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/01309

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
D,A	PACE, Volume 21, No part1, November 1998, J-J Blanc et al., "A Method for Permanent Transvenous Left Ventricular Pacing" page 2021 - page 2024	1-16

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

28/06/00

International application No.
PCT/SE 00/01309

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5902324 A	11/05/99	WO 9955414 A	04/11/99
US 4928688 A	29/05/90	NONE	
US 5720768 A	24/02/98	CA 2248952 A	27/11/97
		EP 0901397 A	17/03/99
		WO 9744090 A	27/11/97
US 5728140 A	17/03/98	NONE	